

Thermophysical Characteristics of OSIRIS-REx Target Asteroid (101955) Bennu

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Abstract.

In this work, we investigate the thermophysical properties, including thermal inertia, roughness fraction and surface grain size of OSIRIS-REx target asteroid (101955) Bennu by using a thermophysical model with the recently updated 3D radar-derived shape model (Nolan et al., 2013) and mid-infrared observations (Müller et al., 2012, Emery et al., 2014). We find that the asteroid bears an effective diameter of 510^{+6}_{-40} m, a geometric albedo of $0.047^{+0.0083}_{-0.0011}$, a roughness fraction of $0.04^{+0.26}_{-0.04}$, and thermal inertia of 240^{+440}_{-60} $\text{Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$ for our best-fit solution. The best-estimate thermal inertia suggests that fine-grained regolith may cover a large portion of Bennu's surface, where a grain size may vary from 1.3 to 31 mm. Our outcome suggests that Bennu is suitable for the OSIRIS-REx mission to return samples to Earth.

Keywords. radiation mechanisms: thermal, minor planets, asteroids: individual: (101955) Bennu, infrared: general

1. Introduction

(101955) Bennu is an Apollo-type near-Earth asteroid (NEA) given its orbital characteristics. Bennu is a potential Earth impactor with a relatively high impact probability of approximately 3.7×10^{-4} (Milani et al., 2009, Chesley et al., 2014). Recently, Chesley et al. (2014) showed that the semimajor axis of Bennu drifts at an averaged rate $da/dt = (-19.0 \pm 0.1) \times 10^{-4}$ au·Myr⁻¹ due to the Yarkovsky effect, and further predicted dozens of potential impacts for this asteroid from 2175 to 2196. Since its orbit makes it especially accessible for the spacecraft, Bennu is considered as one of the potentially hazardous asteroids (PHA) and was chosen as a suitable target for NASA's OSIRIS-REx sample return mission (Lauretta et al., 2012). The OSIRIS-REx spacecraft is scheduled to be launched in 2016.

Several researchers investigated the thermophysical features of Bennu. Müller et al. (2012) derived Bennu's thermal inertia of $\sim 650 \text{ Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$ with thermophysical model, based on observations from Herschel/PACS, ESO-VISIR, Spitzer-IRS and Spitzer-PUI. Recently, Emery et al., (2014) showed an update thermal inertia of Bennu approximately $310 \pm 70 \text{ Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$ from a thermophysical analysis of Spitzer-IRS spectra and a multi-band thermal lightcurve. There are two main different aspects between the work of (Emery et al., 2014) and (Müller et al., 2012): first, the former considered a 3D radar-derived shape model by (Nolan et al., 2013) in the modeling process, whereas the latter adopted a simple spherical shape model; second, the mid-infrared observa-

tions they used were not identical, in that IRAC and IRS peak-up data were included in Emery et al., (2014), but not utilized in (Müller et al, 2012).

In this paper, we adopt independently developed thermophysical simulation codes from (Yu, Ji & Wang 2014) based on the Advanced Thermal Physical Model (ATPM) (Rozitis & Green 2011), to investigate the surface thermophysical characteristics of Bennu. In our modelling process, we utilize Bennu’s radar-derived shape model given by (Nolan et al., 2013) rather than a spherical approximation shape (Müller et al, 2012). Moreover, we added the mid-infrared data gathered from four groups of observations, at various phase angles, by Spitzer-PUI, Spitzer-IRAC, Herschel/PACS and ESO VLT/VISIR (Müller et al, 2012, Emery et al., 2014). By fitting all observations, we obtain a thermal inertia of Bennu that is slightly lower than that of (Emery et al., 2014), which indicates an important evidence of the fine-grained regolith on Bennu’s surface (for details see Yu & Ji 2015). Moreover, using the derived thermal inertia, we estimate the grain size of the regolith from a thermal conductivity model of (Gundlach & Blum 2013).

2. Analysis

Figure 1 shows a contour of χ^2 in the 2-dimensional parameter space (Γ, f_R) , where the increase of χ^2 is shown by color bar from blue to red. The black ‘+’ corresponds to the minimum χ^2_{\min} . And in this case, we have $\Gamma = 240 \text{ Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$ and $f_R = 0.04$, as best fit solutions to the observations. The blue curve is the profile of $\chi^2_{\min} + 1$, which is assumed as the 1σ limit of the free fit parameters Γ and f_R . The blue profile forms a closed region in the (Γ, f_R) space. Thus, we can simultaneously constrain thermal inertia and roughness fraction in 2-dimensional space, considering the 1σ limit. However, the contour curves of χ^2 above 1σ cannot form closed regions, suggesting that the degeneracy of thermal inertia and roughness fraction cannot be removed so well like the 1σ level, thus thermal inertia and roughness fraction may be simply separated at the 1σ level based on the ATPM calculations. Therefore, if the 1σ limit is reliable, we may safely conclude that the roughness fraction is possible in the range of 0~0.3, and the thermal inertia may be in the range of $180 \sim 680 \text{ Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$. Our results agree with both earlier investigations of (Müller et al, 2012) and (Emery et al., 2014).

With the above derived thermal inertia, the grain size of Bennu can be estimated according to the method of (Gundlach & Blum 2013). A mean surface temperature $T = 300 \text{ K}$ is assumed in our computation. The other parameters are taken from (Gundlach & Blum 2013). Based on the thermal inertia $\Gamma = 240 \text{ Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$, the grain radius is likely to be in the range $2 \sim 5 \text{ mm}$. In addition, the grain radius may be estimated as ranging from 1.3 to $\sim 31 \text{ mm}$ considering 1σ range of thermal inertia. On the basis of this estimation of grain radius, we infer that boulders or rocks may be few on the surface of Bennu, suggesting that the Touch-And-Go Sample Acquisition Mechanism (TAGSAM) designed by the OSIRIS-REx team should find an accessible environment to operate successfully.

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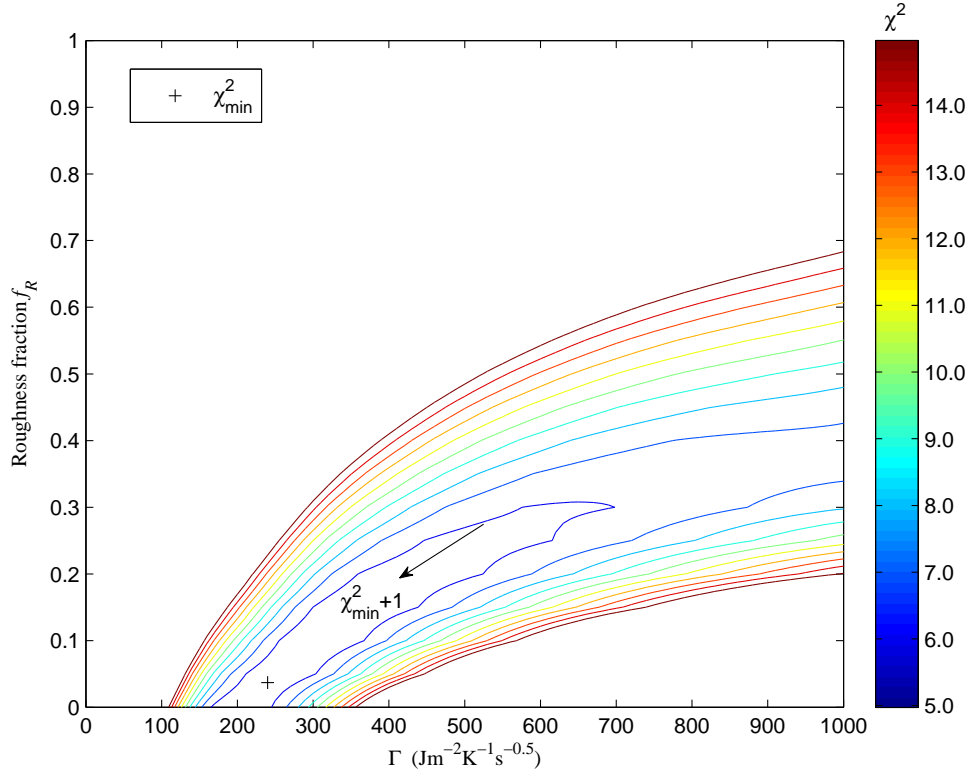


Figure 1. χ^2 (Γ , f_R) contour according to ATPM results. The color (from blue to red) relates to the increase of profile of χ^2 . The blue curve labeled by $\chi_{\min}^2 + 1$ is taken as the 1σ limit to the free fit parameters (Emery et al., 2014, Bevington & Robinson 2003).

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